

1 **TITLE: HIGH RELIABILITY-PARALLEL DATA TRANSFER HARD DISK DRIVE**

2 **BACKGROUND OF THE INVENTION**

3 **1. Field of the Invention:**

4 This present invention relates to magnetic disk storage systems, and more particularly,
5 to a high reliability high performance hard disk drive systems having a unique structural
6 organization, which includes special focus on isolating the disk area to four quadrants-based
7 on the Cartesian system of coordinates- and read/write functions thereof with respect to
8 timing. Out of which it has concurrent access to two quadrants and both sides of a disk in an
9 instant in time. System has two pairs of actuator-carriage arms with multiple read/write
10 head/disk interface regions, which regions offer greatly enhanced performance regardless of
11 system size (i.e., media form factor). Continuous micro-pad contact and low fly height read
12 and write and the use therefore of a low-mass, low fly height head/structure-suspension (both
13 integrated as a single unit,) are key contributors at this interface regions. The invention can
14 be used in any size rigid-disk system (size independence) that enables application of the
15 invention for all small-media-form-factors as well. The number of platters can be increased
16 to three or four or more.

17 **2. Description of the prior art.**

18 Magnetic hard disk drives are used as the primary storage devices for a wide range of
19 applications, including desktop, mobile and server systems. Demand for disk storage is
20 increasing 60%-70% per year on a worldwide basis. In near future, consumer electronics and
21 computer games and other media applications are very likely to form the basis for additional
22 demand growth facing the disk drive industry.

23 A typical hard disk drive is made of a stack of closely spaced rigid disks, with

1 actuator arms that carry very small magnetic transducer heads that move radially within the
2 said stack of disks in a comb-like manner.

3 Since certain form factors have become standard in the industry, hard disk drive
4 systems must be compatible to sizes of these form factors. Therefore, based on this
5 constraint, increases in memory capacity of a hard disk drive of a given standard size are
6 possible either by increasing the density of data written on a given area of a disk or by
7 improving mechanical design. The trend has been towards smaller form factors.

8 The technologies involved in magnetic storage products generally are in one of the
9 following categories: a) Technologies that pertain to the geometric formation of the heads for
10 the contacting or non-contacting way of operation. b) Technologies that pertain to the design
11 of the head/disk assembly that serves the operation of the read/recording heads,
12 c) Technologies that pertain to the control and recording electronics, d) Technologies that
13 pertain to the composition of the magnetic coating and lubricants.

14 Among the most important disk drive performance measurements are: a) Formatted
15 box storage capacity, it measures storage capacity per unit of volume and has increasingly
16 become more important as space is limited in desktops, and especially notebooks, laptops and
17 other small portables; b) average access time to data, it is very important as it determines the
18 time required to locate or store data and , c) data transfer rate, it is important as the disk drive
19 data transfer rate influences overall system performance.

20 Reliability is the number one priority for users, number two priority is cost, but
21 improved access time is also important-despite already improved fast seek times achieved.
22 Therefore, different magnetic head positioning-actuator arms and drive arrangements have
23 been designed to achieve such improvements, besides increasing the number of the disks.

1 Prior art magnetic positioning mechanisms-actuator arms developed are of two main
2 type. Linear positioners are made of a carriage to carry actuator arms that are moved radially
3 relative to the axis of the rotation of the disk to position the magnetic heads along multiple
4 circumferentially positioned tracks. Pivotal actuator arms pivot on an axis parallel to the axis
5 of the disks, thereby magnetic heads are carried at the ends of the arms and move in arcuate
6 paths over the magnetic tracks of the disks. Current commercial hard disk systems employ
7 mostly a conventional planar moving coil actuator assembly.

8 Prior art moving coil actuator assembly consists of an analog voice coil, a carriage
9 arm, a suspension and head gimbal assembly member and a pivot member. The electro-
10 magnetic actuation force $F_{sub.A}$ becomes effective at one end of the carriage arm in order to
11 actuate the head positioning assembly. This results in a reaction force $F_{sub.P}$ that is
12 effective on the pivot member, since the force $F_{sub.A}$ is a non-coupled force. The reaction
13 force $F_{sub.P}$ causes a vibration on the actuator assembly at about the pivot member, usually
14 in a track seeking direction. This Quasi-Rigid body vibration mode is at mid band of about
15 4.about.6 KHz. Conventional planar moving coil actuator assembly usually has a track
16 density of 6000.about.8000 TPI. The head positioning of these systems have a cross over
17 frequency of 500.about.700 Hz, that can be sufficient for only 12000.about.14000 TPI.
18 Whereas, the increasing trend of higher TPI makes fine-precision head positioning even more
19 important and critical.

20 The current state of the art read/write heads operate at a distance of the order of 0.1-
21 0.5 micron above the disk surface. This height-as per straight arm actuator and suspension
22 system- being a microscopic distance; a range of 0.000004 to 0.00002 inch of fly height, has
23 the potential danger of head crashes and loss of data when for example an unexpected

1 impact-shock occurs to the desktop or to the notebook as the system is running-and this
2 causes the head to ding as it is called in the field, to the hard disk surface, or sudden power
3 failures result in head crash, or damage to heads or to surface. Nevertheless, it is desirable to
4 have a fly height as close to the recording media as possible.

5 The low fly height and increased recording density can be understood from the
6 following equation that expresses the dependence of the length of a pulse width PW50
7 obtained from a recording transition on the recording system.

$$8 \quad PW50 = \{g^2 + 4(d+a)(d+a+\delta)\}^{.sup.1/2} \quad (1)$$

9 where

10 g = gap length of the recording head

11 d = the distance separating the head and media

12 $a = 2 M_r \delta / H_c$ (length of a recording transition)

13 δ = film thickness

14 $M_r \delta$ = magnetization-thickness product

15 H_c = coercivity

16 This equation was provided by Williams and Comstock in "An Analytical Model of the Write
17 Process in Digital Magnetic Recording, 17th Annual AIP Conference Proceedings, part 1,
18 No.5, 1971, pp.738-742, American Institute of Physics.

19 Furthermore, disk tangential velocity is greater at outer tracks than at inner tracks that
20 result in different wind speeds based upon where the slider is positioned. In rotary actuated
21 drives, the slider changes skew angle from inner tracks to outer tracks. These differing wind
22 speeds and differing skew angles cause variations in fly height.

23 Invention assumes zero disk slippage-therefore zero variation in track radius by

1 runout and track distortion as a result of using high quality spindle and clamps.

2 Another problem with prior art hard disk drives is that at specific time intervals
3 during normal operation of hard disk drive, a sequence called Servo Bank Write (SBW) is
4 performed. At this time, write heads write position data to all of the servo wedges at the
5 same time. In prior art hard disk drive systems, the sensitive read heads are subject to voltage
6 variation in the SBW mode, where bias current can drop from $I_{\text{sub.bias total}}$ in the read mode
7 to $I_{\text{sub.bias total}}/N$ in the SBW mode, that could result in read head damage. This problem is
8 addressed by U.S. Patent No. 6,594,101 entitled; Read Head Protection Circuit and Method,
9 and can be implemented for the purposes of the present invention-it would be especially
10 relevant, as a multiple number of read/write heads are employed in the present invention.

11 Furthermore, whenever the drive motor is turned on and off, the slider undergoes a
12 sliding contact with a portion of the disk. This contact between the slider and the disk when
13 the drive is turned on and off is known as contact start stop (CSS) operation. This CSS
14 motion is a major cause that lowers reliability as the drive gets older and therefore reduces
15 reliability in the long run. 20,000 CSS cycles for desk top and 100,000 CSS cycles for
16 portable computer applications is considered proper. A higher number of CSS cycles is
17 needed especially in systems where these are turned on and off frequently. A higher CSS
18 number also means a longer product life expectancy and reliability.

19 Friction is related to two important problems: 1) Power consumption, 2) Head
20 vibration. Lower power consumption is very important for battery-powered laptops,
21 notebooks and portable systems. For these systems, power consumption due to interface
22 should be a small fraction of 800mW. With respect to friction sliding and stiction, these
23 constraints are addressed by U.S. Patent No. 5,949,612; entitled Low Friction Sliding Hard

1 Disk Drive System, where the continuous sliding and the disk surface adhesion reduction
2 texture that has a microscopic RMS roughness aspect that also reduces capillary adhesion,
3 can be made compatible with minor adjustments and be applicable for the purposes of this
4 invention. The friction must be minimized between the slider and the disk. Therefore, the
5 solution of the invention to this problem is one continuous contact micro-pad per two thin
6 film transducers.

7 Among various causes, the main cause of data loss is hard drive failures. The overall
8 cause of data loss due to hard drive failures is a very high rate of 65%. For small and mid
9 size companies, those that can not or have not made an investment in additional back up
10 systems, data loss due to hard drive failures can mean great economic losses and may even
11 result in business failures.

12 Among all hard drive failures, stiction accounts for about 60%. It is defined as the
13 force it takes to get an object at rest on another object to start sliding. It is measured in grams
14 to indicate the force required to separate the slider from the disk. The second type of stiction
15 is called parking stiction and is a term used to indicate when the drive has not been in use and
16 has been in the CSS zone. One reason of stiction is that some drives are lubricated with
17 shellac or lacquer or other lubricants-when these get hot these liquefy. When drive is turned
18 off, heads come to rest on the surface of CSS zone and the coating solidifies as the drive
19 cools-and acts like a glue that keep the heads on the platter. Spindle failure accounts for
20 about 15%, failed electronics on the drive account for about 20%.

21 The recovery services provided by data recovery companies for hard disk failures and
22 to recover valuable data are very costly. Depending on the type of drive, it starts from \$3,000
23 to \$12,000 to recover data from a hard disk-if recoverable at all.

1 The straight-arm actuator system-which is a standard on most disk drives-is actually a
2 system with inherently problematic structural and functional aspects.

3 First major problem is the limitation of the straight-arm actuator with respect to the
4 disk area that it can cover simultaneously at any given instant in time. The straight-arm
5 actuator can not cover different quarters of the disk concurrently at any given instant in time.
6 Therefore, it must make many swinging motions-usually on one area arcuate trajectory to
7 reach tracks that are located at many different concentric areas of the disk. Post boot up
8 normal operational conditions, the single straight-arm actuator and similar variations of the
9 same system have to make relatively long back and forth distance motions over the disk, as
10 well.

11 Given the increased density of tracks, increased precision is needed. Despite the swift
12 motions of the straight arm actuator, reaching the different tracks on the many different
13 concentric areas of the disk is not instantaneous and requires many motions that involve
14 sudden direction reversals of the straight-arm actuator that also have to be precise. The
15 trajectory from the inner most tracks to the outer most tracks is a relatively long distance and
16 as track densities increased, the precision demanded from the actuator system has been
17 increasing substantially, since state of the art disks can have up to 20.000 tracks or more.

18 However, second, these motions of the straight-arm actuator and the associated
19 read/write head assembly are subject to vibrations. Vibration has adverse effect on these
20 small and sensitive components, including head vibration. Head vibration depends in part to
21 mechanical resonance of slider-which generally increase with friction. Reduction of friction
22 reduces both power consumption and head vibration.

23 Higher rpm is chosen as a way for fast access. However, this creates a third problem,

1 high rpm has the problem of creating excess heat and is more demanding on the spindle
2 motor. For example, state of the art 10,000 rpm drives reach a temperature of 100 F and
3 above during intensive use. Such a temperature is not tolerable in a cramped case without
4 extra cooling. Additional cooling has both space and cost constraints. Furthermore, high
5 rpm has more wear and tear-instability potential, especially in systems that are frequently
6 turned on and off.

7 Fourth problem with any type of straight arm actuator system involves the constraint
8 of having to park the R/W heads away from data tracks to a zone near the spindle, before the
9 platter stops turning, because it depends on a microscopic distance of air cushion, that in turn
10 depends on the turning of the disk that must not have any variation in the rpm during
11 operation. When system is turned off or due to unexpected power failures for instance the
12 constraint of having to park the heads come up. Parking the heads involves moving the
13 read/write heads all the way to the parking zone-and to land heads, to a region that is located
14 at the innermost reach of the head positioning system, each and every time the system is
15 turned off. Then the heads must take off and then be moved back to data tracks when system
16 is turned on.

17 Therefore, fifth, additionally because of microscopic fly height of the R/W heads,
18 there is always the potential for damage to both R/W heads and damage to the substrate on
19 the disk as the system is running-for example when the system is subject to external
20 inadvertent shocks-bumps.

21 Sixth, these frequent motions also involve interruptions of reading or writing data
22 streams. With a single straight-arm actuator, only serial data transfer scheme is possible. In
23 serial data transfer scheme, the actuator first positions the R/W heads over a certain data

1 track, then data is read or written with one head at a time then the data stream is interrupted
2 as actuator moves heads to a different track. Due to frequent interruptions, the data transfer
3 rate is much slower as compared to a parallel computing transfer scheme with continuous
4 data stream.

5 These back and forth swings over a relatively long distance are erratic. This is
6 especially true during the parking and boot up sequences, that are often repeated and hence in
7 the long term, these sudden swings each time the system is started and turned off cause wear
8 and tear. As a result, the system has lower reliability and lower product life expectancy.

9 Therefore, there is a need for an actuator mechanism that is: a) not subject to contact
10 start stop (CSS) operation method and; b) not subject to Quasi-Rigid body vibrations and
11 relatively high vibrations due to frequent direction reversals during the booting and parking,
12 that is, there is need for an actuator system with lower-minimized vibration rates; c) based on
13 concurrent access to more than one area of the disk surface at any given instant in time, by
14 using more than one linear actuator and also because of a special geometric shape of the
15 actuator-carriage arm that holds a plurality of R/W heads, it is able to read/write on multiple
16 tracks, concurrently; d) not depended on high rpm that creates heat and/or is more
17 demanding on spindle motor; e) Based on a constant R/W head low fly height that always
18 remains at the same-constant fly-height-without the parking of R/W heads, with thin film
19 R/W heads that have reduced interface surface; and f) based on an uninterrupted data transfer
20 scheme-as in parallel data transfer scheme.

21 SUMMARY OF THE INVENTION

22 From the foregoing, it may be appreciated that a need has arisen for a method and
23 apparatus for an actuator system and carriage arm that avoids the constraints of the prior art

1 and is also more reliable.

2 In accordance with the present invention, the above shortcomings of the former hard
3 disk drive actuator arm system, is effectively overcome by a double integrated actuator arm-
4 suspension assembly that moves upon a stationary micro-rail. Transducer head read/write
5 head (denoted R/W hereinafter) height is based on a continuous contact pad assisted constant
6 fly height that has a unique parking method.

7 It is an objective of the invention to provide a system can be applied to all form
8 factors, where it would be proportionally smaller and fit into a small formatted box storage
9 capacity, such as form factor 2.5 inch or 1.8 inch, 1 inch or even special application smaller
10 drives, so that same system can be applied on a variety of systems as notebooks and laptops,
11 and for special purpose applications-such as in special vehicles as in air crafts, space crafts
12 and the like-of very small form factors-since small form factor is correlated to better shock
13 resistivity .

14 It is an object of the invention to have a multiple number of R/W heads feature that
15 would be possible and compatible with the high speed chips and processors.

16 It is an object of the invention to provide a system that has a logic that divides the
17 total area of the disk to four quadrants with respect to an instant in time and the ability to
18 have concurrent access to two quadrants at an instant. An instant in time is to be understood
19 as a very short period in time between 5 ms to 15 ms. Thus it is based on an instant in time
20 as correlated to the relative positions of the two pair of actuators and their concurrent access
21 with respect to time.

22 The system consists of at least; a. one platter; b. Spindle, c. Dual actuator arm
23 assembly that are made of two actuator arm members; d. at least one analog voice coil motor-

1 magnetic movers, e. at least two stationary micro-rails that extend transversely over a platter
2 from the perimeter edge to spindle external cover. f. Connection and moving members,
3 g. Inner and outer actuator units; h. R/W heads.

4 It is an object of the present invention to provide a high reliability actuator arm
5 assembly system that has the two stationary micro-rails feature, upon which the curved wing
6 shaped pairs of actuators move-isolating area of disk in sectors and thereby reducing the total
7 distance each actuator has to cover to a small fraction of what prior art straight arm actuator
8 has to cover, therefore to eliminate the possibility of head ding and head crush failures that
9 could be the result of stiction or other reasons, inclusive inadvertent external shocks.

10 Furthermore, actuator system can do the same main tasks by moving within a shorter
11 distance with better precision and can complete tasks faster, such as boot up, formatting,
12 scandisk, defragmentation, compression, backup, maintenance and servo bank write, where
13 these involve the constraint to reach the entire or most of the area of the disk. During normal
14 drive operation, write/retrieve functions can be done fast and precisely. As a consequence,
15 micro-actuator and associated wiring and other related micro-mechanic complications would
16 not be involved.

17 It is an object of the invention to provide a HDD system that would not be adversely
18 influenced by the unstable and vibrating conditions as within a mobile system as in an
19 airplane or ground transportation vehicle.

20 It is an object of the present invention to provide a double, independently moving
21 linear actuator and carriage arm and suspension system that enable the R/W functions to be
22 made on two quadrants, and on both surfaces of a stack of disks simultaneously at any given
23 instant. Each pair of wing shaped actuator and carriage arm components move on the linear

1 micro-rail system, and can enable R/W functions to be carried out on multiple tracks and on
2 both quadrants of the disk, with independent motions-moving upon the linear stationary
3 micro-rails-and both sides of a stack of platters.

4 Due to the capability to reach different tracks at different concentric areas of the disk
5 instantly and concurrently while each actuator has to move less frequently and within a
6 considerably shorter range, system enables better precision.

7 Reduced optimal rpm is considered desirable to avoid heating problem that is
8 associated with high rpm. High rpm is more demanding on spindle motor and since the time
9 period-instant is much less than a second-few milliseconds-increased rpm is not relevant.

10 Therefore, rpm greater than 5400 rpm is considered as high rpm. Above 7200 rpm is
11 considered as very high rpm and excessive for the purposes of the present invention.

12 Therefore, it is further an object of the invention, in a first embodiment, to provide an
13 optimal rpm of the disk that is compatible to said actuator system that can eliminate heating
14 problem that occurs with high rpm drives. That is, to reduce the high rpm to an optimal
15 lower rpm and thereby to eliminate both the heating problem of the high rpm of the prior art
16 hard drives, as well as to reduce the power requirement and to reduce the stress on the spindle
17 motor due to the higher rpm, that occurs especially because of stops and starts.

18 It is further an object of the present invention to provide an actuator-carriage arm
19 system and associated R/W head assembly that minimizes or eliminates the vibrations on said
20 actuator section and said associated R/W heads by minimizing the frequency of sudden back
21 and forth direction reversals for reaching different tracks far apart.

22 It is further an object of the present invention to provide an integrated actuator-
23 carriage arm system that can provide an uninterrupted data transfer scheme.

1 It is further an object of the present invention to provide an actuator-carriage arm and
2 suspension system and associated R/W heads with a continuous micro-pad contact operation
3 and constant low fly height-where two R/W transducers are each next to one continuous
4 contact pad and have reduced size thin film transducers of non-physical contact type to
5 reduce the dynamic friction substantially.

6 It is further an object of the invention to provide a wear-resistant coating that assists
7 the continuous micro-pad contact that have minimized area of contact, thereby enables a
8 multitude of R/W heads to be functional without causing wear on both the R/W heads and
9 disk surface.

10 It is further an object of the invention to provide a hard disk drive that has a higher
11 rate of reliability and a longer product life expectancy as a result of the sum of the above
12 mentioned properties. As a result, the actuators of this invention enable faster seek-retrieve-
13 write that also have better precision due to motions that take place within a considerably
14 shorter range, i.e. integrated micro-actuation function.

15 In the preferred embodiment, the independent double linear micro-rail actuator system
16 is made of two independent stationary micro-rails that are stationary over two different
17 quadrants of the disk, on which four wing shaped actuators-carriage arms in total move
18 linearly. Each curved wing shaped actuator-carriage arm, hereinafter called actuators have
19 multiple R/W heads that are in a series of curvilinear formation that conform to the curves of
20 the tracks of the disk. Conforming to the curves of the tracks is to be understood that the
21 plurality of R/W heads are in such a series and affixed under said actuator in such precise
22 angles, that the R/W heads conform geometrically to the curves of at least several adjacent
23 tracks simultaneously, without having to make additional actuator positioning adjustments

1 most of the time or with only very minor distance adjustments. (See fig. 17.) The geometry
2 of the actuator and the multiple R/W heads conform to the track curves-arcs, so that they are
3 positioned over the tracks exactly in a curvilinear configuration, instead of a head actuation
4 system of the prior art-where fewer number of R/W heads have to constantly swing over and
5 has to be re-positioned tangentially over longer distances. Hence, even as the actuators are
6 not moved and remain over a certain arc-like area, a multitude of data tracks can be read and
7 written upon at that instant and many complete sectors in a row can be read without
8 interrupting the data stream, since the R/W heads do not have to be repositioned very
9 frequently-as these have to be in the prior art.

10 Based on this system, it is possible to position the two pairs of wing shaped actuators-
11 carriage arms in such a relative position at an asymmetrical position that, even when
12 positioned asymmetrically, the concentric area of disk is divided to four. (i.e. inner concentric
13 and outer concentric tracks times two.) When positioned symmetrically (see figure 6,) over
14 same concentric tracks that pass through both quarters and below both actuators and heads,
15 this results in a division of the total concentric area also to four, but in addition it enables
16 very fast-instant access, even as the wing shaped actuators-carriage arms do not change
17 position and remain stationary at that instant.

18 It is further an objective of the invention to provide a low constant, non-variable fly
19 height, that eliminates problems associated with R/W heads parking requirement that
20 involves landing the heads to a surface-zone near the spindle of the prior art, and also
21 eliminates fly height variation that occurs as a result of depending on the thin air layer that
22 lifts the transducer in the prior art. Also eliminated is operation head-substrate wear and tear
23 in the long run. In order to have even higher accuracy under the low fly height, the

1 transducer heads gap width is of reduced type. Since each actuator area of motion-coverage
2 is limited-reduced fly height becomes possible-with less friction -as each actuator moves only
3 within a designated shorter-limited distance of the radius of the disk, (i.e. linearly within each
4 1/2 of the radius.) Low fly height allows high coercivity media that in turn enables a
5 narrower transition length "a".

6 It is further an objective of the present invention to provide a second embodiment
7 with higher spindle speed-rpm, a very fast data access time and to considerably increase the
8 external data transfer rate.

9 It is further an objective of the invention to provide a third embodiment of the system,
10 where the Blue tooth technology would be applied within -a localized micro range- within the
11 drive between transducer heads and drive electronics control board and thereby the need to
12 connect flexible printed circuit (FPC) board electronics wiring between the heads-actuator-
13 carriage arms and drive electronics control board units would be eliminated.

14 These and other objects of the present invention will be more evident as depicted by
15 the drawings.

16 DESCRIPTION OF THE DRAWINGS

17 Figure 1 is a top view of a prior art hard drive that uses a straight-arm actuator arm.

18 Figure 2 shows is a top plan view of the double independent linear micro rail
19 actuator- carriage arm and suspension system that is able to have two different
20 circumferential areas concurrent positioning based on dividing the total disk area into two
21 areas of inner most tracks and the outer most tracks. Also depicted are the two pairs of wing
22 shaped actuators-carriage arm geometry that forms multiple R/W heads to be compatible to
23 said geometry, that generally conform to the curves of the tracks.

1 Figure 3 is a top plan view, of the actuator-carriage arm system that has concurrent
2 access by wing shaped actuators to two main quarters that results in accessing four different
3 concentric areas of tracks concurrently. Also depicted is one of the flexible printed circuit
4 (FPC) board that has the wiring board connection which has signal lines that connect
5 magnetic heads to the drive electronics board.

6 Figure 4 is a perspective view, showing the concurrent two quarters actuator-carriage
7 arm and suspension system with the wing shaped arcuate arms. Also depicted is the flexible
8 printed circuit (FPC) board electronic wiring connection that connects the actuator and R/W
9 heads to the drive electronics board.

10 Figure 5 is side elevational view of one-half of the disk area showing how the R/W
11 heads are positioned and move linearly on the micro-rails.

12 Figure 6 is a top plan view of the two pairs of wing shaped actuator-carriage arm
13 system and how this results placing a set of tracks 24, 25 under R/W heads 26 by only a 1/2
14 tour of a complete revolution of the platter-for both pairs. Also depicted are the flexible
15 printed circuits (FPC) board electronics wiring connection to said wing shaped actuators that
16 connect actuator and R/W heads to the drive electronics board.

17 Figure 7 is a top plan view one of the wing shaped actuator-carriage arm and
18 integrated suspension with the cutaway view of the R/W heads.

19 Figure 8 is a perspective view of one of the inner side wing shaped actuator-carriage
20 arm and integrated suspension and the R/W heads that fly over the disk surface.

21 Figure 9A is a side elevational view of a prior art transducer head with a wider head
22 gap width as compared to the narrow head gap width of the invention-figure 9a.

23 Figure 9B is a side elevational view of the thin film head of the invention with a

1 narrower head gap width and a reduced area of the transducer.

2 Figure 10 is a side elevational view of the actuator arm and the R/W heads affixed
3 thereon, which move at constant low fly height over the disk surface.

4 Figure 11 is a perspective view of, one of the disassembled wing shaped pair of
5 actuator arms above the micro-rail, with the cylindrical actuator which get into the circular
6 cavities of the stationary rail. The stationary micro-rail, with the circular cavities is depicted
7 just below the wing shaped actuator and its two cylindrical members.

8 Figure 12 is a top plan view of a pair of wing shaped actuators and the angle of data
9 tracks, as well as the member that moves the pair of actuators.

10 Figure 13 is a sectional side elevational view of a pair of actuator-carriage arms and
11 how the two cylindrical rail members move within the micro-rail cavity.

12 Figure 14 is a top view of the actuator-carriage arm that shows how the heads are at
13 parked position on the concentrically aligned non-data zones.

14 Figure 15 is a top view of the actuator-carriage arm 13,

15 Figure 16 is sectional view of actuator arm 13 as seen along line 41-41 in figure 15.

16 Figure 17 is a partial plan view of the multiple R/W heads with the cover plate of
17 actuator arm completely removed and their positions that conform to a series data tracks by
18 forming a set of arc angled R/W heads.

19 Figure 18 is a partial top view of the prior art actuator arm R/W head movements
20 angle and distance relationships with respect to a given set of data tracks.

21 Figure 19 is the sectional side elevation view of the micro-pad and the integrated thin
22 film transducers.

23

DESCRIPTION OF THE PREFERRED EMBODIMENT

The system of this invention can be described by the following formula:

Concurrent-timing access to two quadrants of disk area $< (\text{in every } \frac{1}{4} \Pi \text{ radians per one revolution of disk}) \times 2 \text{ (quadrants)} \times 4 \text{ (two pairs)} \times 2 \text{ (both sides of the number of units of platters)} - (2 \text{ sides of upper most and lower most disks of the stack of disks.})$

With reference to figure 1, the prior art has a rotating disk 10 and carriage arm 10c, where the transducer head 10b moves along a path 10a. At that instant the transducer head 10b can only access tracks that are on quarter 10d. Tracks on quadrant areas 10e, 10f and 10g are not accessible by the straight-arm actuator 10c at that instant in time. For example for any track on quarter area 10g to be accessible by transducer head 10b, the disk 10 must make many more revolutions than one single revolution or less than one revolution and even then the carriage arm 10c has to make many swinging motions on the path 10a until the desired track becomes accessible. The back and forth motions-direction reversals also involve vibrations as is indicated by 10h.

With reference to figure 2, the wing shaped dual actuation arm assembly 13 and 14 are able to reach concurrently two different quadrants 20 and 21 respectively of the disk 33. The reference center line C divides the half of disk 33 area further into two equal halves to indicate the limit that one of the pair member that reaches the inner reach border of actuator 13, that is, it shows the inner limit of the distance 17a that one of the pair member of wing shaped actuation-carriage arm 13 moves within the $\frac{1}{2}$ quarter area, $\frac{1}{2}$ of the radius of disk 33. Similarly the inner actuator member 14 moves within limited distance 18. Wing shaped dual actuation arm assembly structure 13 is moved by a linear analog voice coil motor 12 and wing shaped dual actuation assembly structure 14 is moved by a second linear analog voice

1 coil motor 11 linearly, by moving the connection and mover member 13e (see fig. 7). When
2 the wing shaped actuators arms 13 and 14 are positioned on different circumferential areas, a
3 set of adjacent multiple number of tracks 22 and 23 become accessible for R/W functions.
4 These multiple number of tracks 22 and 23 can reach R/W heads 26a with only less than one
5 revolution of the disk 33. Furthermore, since the wing shaped geometry of actuators-carriage
6 arms 13 and 14 each have a length that extends as an arc like shape along the concentric
7 tracks of the disk 33 and conform to the track curvatures-arcs 22 and 23, not only a multitude
8 of tracks 22 and 23 are reached concurrently, but also many complete sectors in a row 22c
9 and 23c pass under the continuous-uninterrupted reach of the R/W heads 26a for a longer
10 time. Therefore, many complete sectors can be identified instantly-instead of sequentially-as
11 in the serial data transfer scheme. Sector interleaves and head skew would become more
12 effective and efficient. A very fast input-output bus and large buffer in RAM would be
13 needed for this system. Track 22a is the outer most border between inner most tracks and the
14 outer tracks-that divides 1/2 of the radius of the disk to two halves, upon which actuators 13
15 and 14 move. Border tracks 22a of fig. 22a and the inner non-data zone 22d of fig. 14 are
16 located adjacent to each other. Those skilled in the art will recognize that the complete hard
17 disk sectors 22c and 23c depicted are not drawn to scale in FIG.2 , but are rather depicted as
18 much thicker lines for visual clarity.

19 Referring to figure 2-upper right quadrant 21, the cutaway view of the multiple R/W
20 heads 26a shows how the R/W heads 26a are in a series below the wings of the wing shaped
21 dual actuator-carriage arm 14, and face the disk surface 33a. The disks 33 and 34 are turned
22 by a spindle motor 32.

23 With reference to figure 3, the two pairs of wing shaped actuator-carriage arms and

1 suspensions 13 and 14 cover two quadrants 20 and 21 of the disk 33 area concurrently and
2 can move independently. Data track 23a is one set of innermost tracks of the outer most set
3 of tracks, that are located on the outer 1/2 area of the disk 33. Similarly data track 22b is one
4 set of the inner most tracks that are within the inner 1/2 area of disk 33. The limited
5 designated distances 17 and 17a are assigned to each actuator members of the pair actuator
6 13. Similarly, the actuator pairs 14 move within the designated limited distances of 18 and
7 18a. The opposite quadrants 20 and 21 that the pair of actuators 13 and 14 function upon, are
8 the areas over which the system has concurrent R/W capability. Pair actuator arms and
9 suspension 13 moves on linear stationary micro-rail 16. Similarly, the pair of actuator arm
10 and suspension 14 moves on linear stationary micro-rail 15. Also shown is one of the
11 flexible printed circuit (FPC) electronic wiring 13c and 13d connection that connects wiring
12 13a to the drive electronics board.

13 With reference to figure 4, depicted in perspective view are both pairs of wing shaped
14 actuators-carriage arms 13 and 14 that move upon the stationary micro-rails 16 and 15
15 respectively. This pair of actuator arms 13 enables access to two different quadrant areas 20
16 and 21 of the disks 33 and 34 concurrently. Due to the pair of actuators 13 and 14, a
17 multitude number of inner tracks 22 and a multitude number of outer tracks 23 are
18 read/written concurrently with only 1/2 of a revolution of the disk 33 and 34. The flexible
19 printed circuit (FPC) electronic wiring board 13c and 13d that have a wiring pattern that have
20 signal lines that connect the wing shaped actuator-carriage arms 13 and 13a and R/W heads
21 26, 27, 28, 26b, 27b, 28b (all not shown) to the drive electronics board. The reference center
22 line C indicates the inner limit of the outer actuator 13-one member of the pairs that is over
23 the outer 1/2 tracks-of the disk 33, this is the inner limit reaching border for the outer one of

1 the actuator 13. Same applies for actuator arm assembly pair 14.

2 With reference to figure 5, depicted is a partial ½ side elevational view of the disk of
3 the two platters 33 and 34 and the R/W heads 26, 27, 28 and their single continuous contact
4 pad system (not shown in this drawing) per each one R/W head 26, 26a, 27, 27a, 28, 28a that
5 move linearly on the stationary micro-rails 16 and 16a and 16b, by analog voice coil actuator
6 motors 12, 12a and 12b, that also have a digital mode-which enables a fast skip function of
7 data tracks 22, 22a, 23. The half of the disks of 33 and 34 is further divided into two by a
8 reference center-line C to be indicative of the limits of the distance that one of the outer of
9 the pair of the actuator-carriage arm system moves. These R/W heads 26, 27, 28 are able to
10 read/write on disks 33 and 34 surfaces 33a, 33b and 34a and 34b concurrently. The spindle
11 motor 32 of the double platter system is seen at left. The stationary micro-rails 16, 16a and
12 16b cover one of the quadrant areas 20, of the two disks 33, 34 with both surfaces 33a, 33b
13 and 34a and 34b being read and written upon. Note, not shown are the same components that
14 are at the other half-quarter of the disk 33, (left side of figure 5,) for actuator-carriage arm 14
15 and R/W heads 26b, 27b, and 28b and their single continuous contacts pads 26a, 27a, 28a.
16 The micro-rail 15 covers the other half area of the disk 33.

17 With reference to figure 6, the wing shaped actuation-carriage arms 13 and 14 are
18 able to reach concurrently two different quadrants 20 and 21 of the disk area, when these are
19 in a symmetrical positioning-as depicted. When the wing shaped actuators 13 and 14 are
20 positioned symmetrically on the same opposite concentric areas, a set of multiple tracks 24
21 and 25 becomes accessible, this multiple number of tracks 24 and 25 reach R/W heads with
22 only 1/2 of a revolution. The flexible printed circuit (FPC) board 13c and 13d and 14c and
23 14d electronics wiring-signal connection to said wing shaped actuators 13 and 14 that

1 connect actuator and R/W heads 26, 27, 28, and 26a, 27a, 28a (not shown-see drawings 2,5,7)
2 respectively to the drive electronics board. R/W heads 26 through 28a are not shown in this
3 drawing, R/W heads 26a through 28a are the counter part R/W heads of actuator-carriage arm
4 14 that is for quadrant 21.

5 With reference to figure 7, the wing shaped actuator-carriage arm 14 with the cutaway
6 view of the R/W heads 26a that fly over disk surface 33a, where a set of multiple tracks 22
7 and a row of complete-uninterrupted hard disk sectors come under the R/W heads 26a-as the
8 heads 26a need not to be repositioned very frequently.

9 With reference to figure 8, the inner side wing shaped actuator-carriage arm and
10 suspension 13 can move linearly on the stationary micro-rail 16 towards and away from the
11 center of the disk surface 33a and thereby the R/W heads 26 of actuator 13, that fly over the
12 disk surface 33a are capable to read/write on a set of multiple tracks 22b, concurrently. The
13 disks 33 and 34 are turned by spindle motor 32.

14 With reference to figures 9A and 9B, in sectional view, the transducer head 35 of the
15 prior art has a wider head width gap 36 and greater head area 36a as compared to the
16 invention transducer head width gap 37 and invention transducer area 37a. The fly height 39
17 of the invention R/W head 38 is higher by only few microns-and has continuous contact pad
18 43-where fly height of transducer 38 parts are only few microns higher than the lowest fly
19 height applied in the state of the art drives in this industry. In order to reduce the area of the
20 transducers, so that overall dynamic friction is reduced, the transducer head 38 of the
21 invention has a smaller transducer area 37a that fly over disk protective layer 40b and
22 magnetizable layer 40a, as compared to prior art transducer head 35 transducer area 36a that
23 face the disk magnetizable layer 33c. Note, fly height 39 is not to scale. The protective layer

1 of invention is 40b. The magnetizable layer of the invention disk 40 is 40a.

2 With reference to figure 10, the actuator arm 13 moves upon micro-rail 16. The R/W
3 transducer heads 26 and thin pads 43 are affixed to said actuator arm 13 and fly upon disk
4 surface 33a with a constant fly height 40. The actuator 13 moves as its lower cylinder rail
5 member part 13c moves within the cylindrical cavity 16h (not shown in this drawing) of
6 micro-rail 16.

7 With reference to figure 11, the actuator 13 and stationary micro-rail 16 are depicted
8 as these are disassembled. The internal surfaces are such that-enclosed by the micro rail
9 cavity 16h- the cylinder rail member 13c of the actuator 13, moves only linearly-force applied
10 by the analog voice coil motor does not make the rail member 13c to make any upward-
11 vertical, downward or horizontal deflections, since the rail member 13c of actuator 13 is a
12 micro-cylinder and fits exactly to said cavity-as depicted by four sides 16d, 16e and 16f, 16g
13 of micro rail 16. The internal surfaces of cylindrical cavities 16h of said rail 16 have internal
14 and external surface coating 16c that minimizes friction to near zero. Such material is called
15 near zero frictional coating (NFC) invented at Argonne laboratories. Other friction
16 eliminating material could be applied if such is more suitable for this extremely thin layer
17 application that involves very small components. For the form factors of 1 inch and lower,
18 the system would enter the realm of nano-technology, as components and coatings would be
19 proportionally smaller and thinner. R/W transducer heads 26 and thin pads 43 are seen below
20 pairs of actuator-carriage arm 13.

21 With reference to figure 12, depicts in plan view, how the wing shaped pair of
22 actuator arms 13 are able to be positioned over-at a stationary mode and receive a set of data
23 tracks 22 and 23 at an acute angle theta-relative to the actuator arm 13. The connection and

1 moving member 13e, moves the said pair of actuator arms 13 in parallel. Same applies for
2 actuator pair 14.

3 With reference to figure 13, sectional side view depicts the stationary micro-rail 16
4 that have zero friction surfaces 16c within the inner surface of the cylindrical cavity of the
5 micro- rail 16 sides and on upper left and right side corners of the micro-rail 16, upon which
6 actuator arm 13 rail-member 13c glides within. The circular cavities 13c are within the four
7 sides 16d, 16e, 16f, 16g of the micro-rail 16.

8 With reference to figure 14, depicted are the actuator-carriage arm 13 and 14 that are
9 at the parking mode-position when the system is in idle mode or is turned off. The inner
10 members of the pairs of wing shaped actuator-carriage arms 13 and 14, move to a
11 concentrically aligned non-data zone 22d-for inner actuator members- and non-data zone 22e
12 for outer members. This enables the micro-pads 43 and R/W heads 26 and 26a (not shown in
13 this figure-see figures 2, 5 and 7) of said inner member actuators to be positioned over said
14 ring of non-data zone 22d. For both of the outer members of the two pairs of wing shaped
15 actuator-carriage arms 13 and 14, said actuators are moved to a second outer concentric ring
16 non-data zone 22e.

17 With reference to figure 15, this is the top view of actuator arm 13 and its connection
18 member 13e that moves the pair of actuator arms in parallel.

19 With reference to figure 16, this is the sectional view of actuator 13 along the line 41-
20 41. It shows the series of arc formation R/W heads 26 and micro-pads 43 that conform to the
21 arcs of the set of adjacent data tracks 23.

22 With reference to figure 17, this shows the partial plan view of actuator arm 13, with
23 the cover plate of actuator completely removed-showing the multiple R/W heads 26 of the

1 arc like formation, that conform to the data tracks 23. Thereby, this drawing shows the
2 micro-actuation function of the integrated wing shaped actuator arm 13 member of the dual
3 actuator arm assembly. When R/W heads 26 and thin pads 43 move from track origin O to
4 track T7, the actuator 13 enables access to data tracks 23 by moving only a distance $D_{sub.o}$
5 and R/W heads 26 are able to reach a set of points on track T7 and as far as points on track
6 T7.sub.a, as indicated by tangent reference line $D_{sub.r}$, that is the border of maximized
7 reach due to the arc like geometric shape of actuator 13. The group of adjacent tracks are
8 depicted as 23. Distance moved $D_{sub.o}$ makes this distance to be multiplied and to be equal
9 to $D_{prime.sub.o}$. As an example to adjacent tracks 23; actuator 13 makes $D_{sub.o}$ to be
10 equal to the micro distance DT_7 .

11 With reference to figure 18, it is a plan view of the prior art straight arm actuator 10c
12 that must swing over a distance $d_{sub.p}$, as compared to the much shorter distance of the
13 invention $d_{sub.o}$, that actuator 13 of the invention covers for an identical distance in terms of
14 the number of adjacent tracks-from track origin O to track T7. The $D_{prime.o}$ of figure 17
15 equals in distance to $D_{sub.p}$ in figure 18.

16 With reference to figure 19, it is the side sectional elevation view of the continuous
17 contact pad 43 integrated unit 42 that consists of one micro-pad 43 per two thin film
18 transducers 38.

19 In compliance with the statute, the invention described herein has been described in
20 language more or less specific as to structural features. It should be understood, however,
21 that the invention is not limited to the specific features shown, since the means and
22 construction shown is comprised only of the preferred embodiments for putting the invention
23 into effect. The invention is therefore claimed in any of its forms or modifications within the

1 legitimate and valid scope of the amended claims, appropriately interpreted in accordance
2 with the doctrine of equivalents. The invention is capable of other embodiments and of being
3 practiced and applied in various other ways.

4 The device and the method mentioned heretofore have novel features that result in a
5 new device and method for high reliability hard disk drive actuator-carriage arm and
6 suspension system, which is not anticipated, rendered obvious, suggested, or even implied by
7 any of the prior art hard disk drive actuator-carriage arm devices, either alone or in any
8 combination thereof.